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THE INTERPRETATION OF ERTS-1 IMAGERY FOR SOIL SURVEY OF THE MERIDA REGION, SPAIN

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this investigation is the evaluation of the potential of ERTS-1 imagery provided by NASA, for soil survey. The imagery has been related to the results of an aerial survey training and research project, which the ITC Soil Department has carried out in the Mérida region in SW Spain over the past 6 years, in collaboration with Spanish governmental and scientific authorities.

The investigation was made possible by NASA which approved the ITC P.I. proposal and supplied the imagery. Fieldwork was conducted through the generous cooperation of the Spanish authorities which permitted ground truth surveys in May, June and October 1973. These unfortunately could not be completed at the same time as the imagery in March.

Both black and white and colour imagery have been studied using various bands and a number of filter and illumination combinations at scales varying from 1:100.000 to 1:1.000.000 using an I^2S Addcol Viewer and other photographic means. Other experiments with respect to contrast and registration of the original images and converted products were carried out in the ITC Department of Photography.

Preliminary results seem promising. Major landforms and some sub-divisions could be easily recognized. Water bodies, river courses, extensive areas of miocene clays and more recent coarse textured deposits could be delineated and existing soil maps at scales up to 1:100.000 could be updated. It should be stressed that the investigation was completed in a well mapped area; the same favourable results might not have been obtained in an unknown area.

We conclude that the ERTS-1 imagery promises to be very valuable for generalized to exploratory surveys at small scales up to 1:500.000, valuable for reconnaissance surveys at scales up to 1:100.000 and useful for surveys at scales up to 1:50.000 in conjunction with conventional aerial photo-interpretation.

I. INTRODUCTION

The purpose of this investigation is the evaluation of the potential of ERTS-1 imagery for soil survey. The imagery has been related to the results of a survey training and research project, which the I.T.C. Soil Dept. has carried out in the Mérida region in S.W. Spain over the past 6 years in collaboration with Spanish governmental and scientific authorities.

The investigation was made possible by NASA which approved the ITC Principle Investigators proposal and supplied the imagery. Fieldwork was conducted through the generous cooperation of the Spanish authorities which permitted groundtruth surveys in May, June and October 1973. The fieldwork was planned to coincide with several of the days on which imagery for this study was scheduled but unfortunately did not coincide with the time (March 1973) at which the imagery was actually completed. Recently however imagery of the months of September and November 1973 became available.
The area of investigation is approximately 25,000 km^2 and lies in S.W. Spain, close to the borders of Portugal, between geographical longitudes 5°E and 7°E and latitudes 38°N and 40°N (see fig. 1). For part approximately 1200 km^2 around Mérida staff and students at ITC have carried out a soil survey training and research program using aerial photographs. For the remaining part of the area the information consists of a series of maps issued by Spanish authorities in different scales from 1 : 250,000 up to 1 : 1,000,000.

The area offers the attraction of a variety of physiographic soil units, which is one of the reasons it was chosen intially by I.T.C.
The main landforms of the Mérida area are:

1. Alluvial valleys (A), mainly along the Guadiana river, which flows approximately through the center and serves as the main drainage channel for the whole survey area. Some tributary valleys have been delineated separately.
2. Gently undulating to rolling landforms, in which three categories could be distinguished:
   a) Areas (R) characterized by an abundance of more or less rounded pebbles, with a diameter from 3-18 cm, inbedded in the soil matrix. These areas are presumed to be the result of a past braiding river activity.

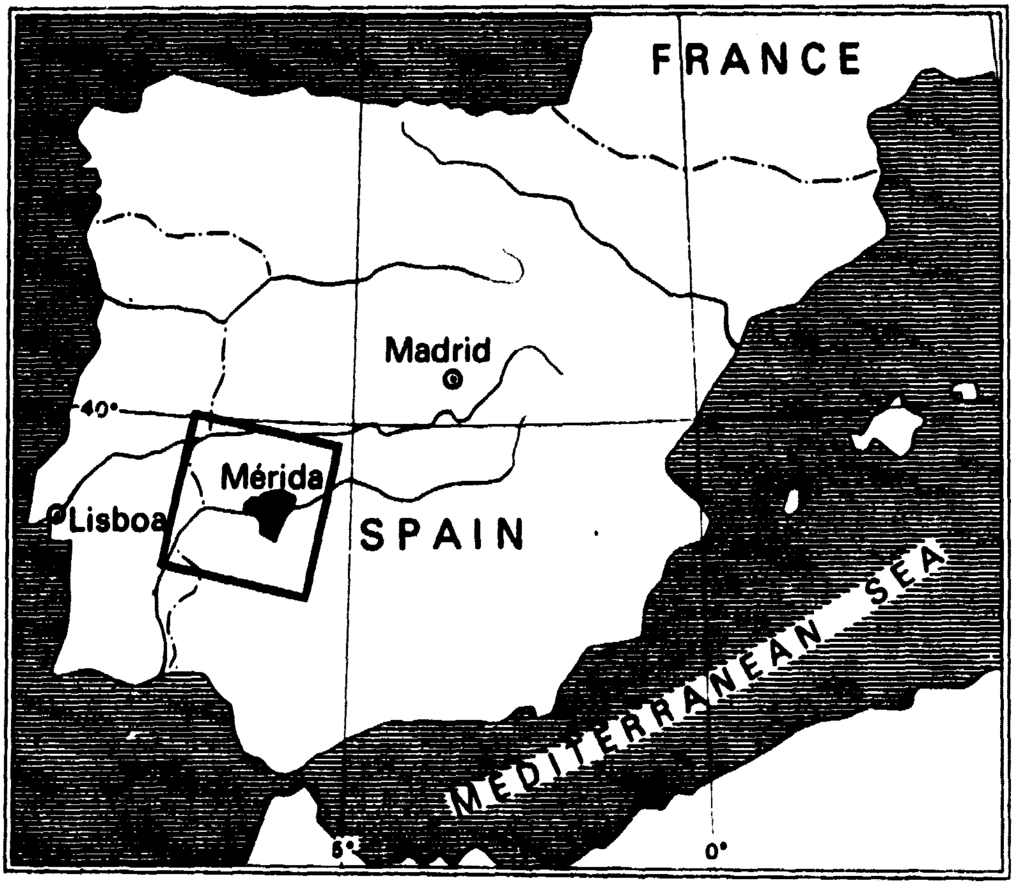


Fig.1 Location map

b) Areas (K) characterized by a coarse sandy top soil with an arkose substratum and

c) Areas (M) characterized by heavy clay soils with a depth varying between 0.25 m to several metres usually containing a calcic horizon.
The parent material dates from the Miocene Period.

d) Areas (C) of low hills and colluvial valleys, characterized by medium textured soils. These areas are situated between the areas of higher hills and mountains (see below).

e) Hills and mountains. They are formed by a variety of metamorphic and igneous rocks varying from schists, quartzites to granites and diorites.
Some of the lower hills and colluvial valleys in between are cultivated, (see above landform (C), the rest are used for pasture if at all.

The most important units from the point of view of agricultural economy of the region are the alluvial and the miocene clay areas. The climate of the region is typical Mediterranean with dry hot summers and moderate winters with an average precipitation between 450 - 500 mm per year.

II. OUTLINE OF STUDY

2.1 General.

Imagery was taken on only few occasions of the test site area by the ERTS-1 satellite, on the 29th of September 1972 and 9th of March 1973. The imagery of September 5th, and November 16th, 1973 could not be used as it didn't become available in time for the present study. Unfortunately, during the passage of the satellite on 29th September 1972, the area had a cloud coverage of about 50%. So the imagery taken, although of good quality from the technical point of view, was not usefull for interpretation purposes. Practically all efforts were concentrated on the imagery of the 9th of March 1973 which was cloud free. Moreover stereoscopy was precluded because the adjacent run was affected by cloud cover.

The imagery arrived at I.T.C., Enschede, in the month of May 1973 in the form of black and white negatives of 70 mm and b. & w. negatives and diapositives of 23 cm format in 1/1,000,000 scale. At that time the fieldwork has already started and the whole of the Soil Dept. had moved to the test site area in Spain. The Photography Dept. of I.T.C. made positive paper prints of the negatives both as contact prints and enlargements of the originals to scales of 1 : 500,000 and 1 : 250,000; for technical reasons, the enlargement to the 1:250,000 scale was limited to only the Mérida Region.
Only 3 of the 4 bands were treated in this way, because the original imagery corresponding with band 4 of the M.S.S. of ERTS-1 was of too poor quality for enlargement. All the products were despatched to the investigators in the field who received them at the beginning of June, and fieldwork continued until the end of June.

2.2 Study of black and white paper print enlargements.

In the early stages of fieldwork the black and white paper prints were examined with respect to the quality of photography, resolution and appearance of various landtypes on different bands. Traverses were completed along main roads, checking was done how each land unit appeared on each band, how far a distinction could be made in the black and white imagery, the limits of resolution, the influence of different elements such as vegetation cover, agricultural practices, texture of top soil, frequency of rock outcrops etc.

Most of the work was done using the 1 : 250,000 enlargements, the others being of rather too small a scale for use in the field.
In the office a visual interpretation was conducted both during the fieldwork period and afterwards at I.T.C. Initially a mirror stereoscope was used with the idea of blending the images of two bands, with the expectation of improving the amount of information received simultaneously, and consequently the validity and accuracy of the interpretation lines. The big difference in contrast between bands created fatigue problems.
Using a red and green filter for each eye reduced the fatigue somewhat but not enough, and unfortunately at the same time the filters created problems of illumination because of the different levels of illumination required to compensate for the differing densities of the filters.
So finally the mirror stereoscope was abandoned and the interpretation was done directly & monoscopically on the paper prints of different bands using a magnifying glass. The resulting interpretation maps were compared with the existing soil maps and other available information to find the possibilities of delineation for various soil mapping units.

2.3 Photographic handling of original products.

During the period of this investigation, close collaboration was established with the Photography Dept. of I.T.C. which held the burden, of handling and enhancing the original products, as received from NASA. The advantage of having at hand an efficient and able photo-laboratory was demonstrated beyond all doubt. The possibilities of feedback between the photo-laboratory and the investigators facilitated the job of both very much. The photographic work was devided into three categories.

a) Improvement of contrast and density in the black and white products.

This was considered necessary because of the difference of contrast and density in the imagery corresponding with the four different M.S.S. bands. Band 4 was especially poor compared with the other bands. The positives were generally to dark with limited contrast. There were 2 results. First the black and white positive of this band was so poor that it had a very limited value for interpretation. Secondly band 4 when in use for producing a color image together with other bands did not contribute enough information to the resulting color image, so that the latter had almost exclusively the information of the other bands.

The improvement was made possible using photographic techniques such as controlled development, dodging etc. The final results improved the original negatives considerably.

b) Double printing of two bands with on or off registration.

In order to facilitate the comparison of the appearances of a certain unit, several two-band paper prints were prepared using as negative a 'sandwich' of a negative and a positive of different bands. This method worked well enough and proved a quick solution to the problem of determining differences over a large area, although for more detailed work a point by point examination was preferable.

Relief enhancement was obtained by off registration (0.2 - 0.3 mm) printing of a 'sandwich' of two different bands or using the negative and positive of the same band. Some lineair features (fault lines, drainage) became much better visible then on the initial imagery. A further bonus of the above prints was the anaglyphic appearance of the final print. The effect of the displacement combined with the appearance of dark tones (lakes and rivers) as lower areas and light grey tones (hill tops) as higher areas gave a substitute for stereoscopy and facilitated in some cases the interpretation.

c) Color composite printing.

A series of color products in the form of paperprints and dia-positives were produced by the photography Departement ITC. These were completed by projecting black and white transparencies of two or three different bands through different color filters on one color sensitive material. A series of different products were made using different band-filter combinations to find those most suitable. Because of registration problems in producing the enlargements a color inter-negative was used before making the final product.

2.4 Use of I^2S Additive Color Viewer, Model 6040.

The I^2S addcol viewer can hold up to four different 70x70 mm images and project them together on a screen with a 2.5 X magnification through different color filters and illumination intensities. It is possible to move every image in X and Y axes and to rotate them around the centre.

Registration of other images than the original 70 mm diapositives, which posses four fiducial marks was done using a clear physiographic feature in the centre of the image of one band as a reference and adjusting the other images accordingly.

The solution for the best filter, band & illumination combination on the I^2S addcol viewer was quite a problem. Theoretically the number of possibilities is very large with two or three band projections using four filter combinations (none, red, green, blue) and an illumination intensity scale ranging from 0 to 10. It was found that each band filter combination should include at least one representative of the group 4 & 5 (preferably band 5) and one of the group 6 & 7. In dealing with the two-band combinations, initially contrasting colors such as red and blue were used for a better differentiation. The results however were not very good, because viewing the picture was fatiguing, probably due to differences in focussing of the human eye for these contrasting colors. A green/blue combination for two bands and red/green/blue for three bnads proved to be easy. The illumination adjustment didn't prove to be a big problem.

After the selection of the best two-band & three-band combinations (by trial & error) the resulting color composite images were photographed using a 35 mm reflex camera (Minolta SRT 101) with both color negative and color positive films. This was done a) to start a file of color pictures for future references and educational purposes, b) to obtain color paper prints for the study and c) to provide a series of slides for the study of the area at different scales.

A draw-back of the I^2S addcol viewer was the fixed magnification of 2.6X. Also the nearly vertical projection screen is not very suitable for drawing purposes. An improved version (model - 6040 PT) of the above addcol viewer has a magnification of 6.7 X and a nearly horizontal projection screen, which make this model more suitable for visual interpretation purposes at a more suitable scale. Stereoscopic vision, a zoom facility combined with an ability to move the screen in X & Y direction would greatly improve the addcol viewer for visual interpretation purposes.

2.5 <u>Field work.</u>

Two periods of field work totalling 2½ months were completed as mentioned previously. The first during the months of May and June and the second at the beginning of October 1973. In total about 7 weeks (70%) were spent in the 1200 km^2 Mérida region for the 1:250.000 map, and 3 weeks (30%) in the remaining part of the 25.000 km^2 test area for the 1:1000.000 map.

There were two purposes for these field visits . The first was the collection of ground truth data to supplement the existing information about the area and the second was to investigate the possibilities of using ERTS-1 imagery as a kind of base map for conducting soil surveys. In the collection of ground truth data we included a series of reflectance measurements of the top soil using an ERTS ground-truth radiometer that operates at the same frequencies as the M.S.S. system of the ERTS-1 satellite. Unfortunately these series of measurements were far from complete due to cloudy weather at the time of field work.

During the second period of field work in October 1973 a series of approximately 70 preselected points were surveyed in the general survey area, but mainly outside the area that has been investigated by ITC in the previous years using ordinary aerial photographs. The points were selected along main roads, on the basis of visual interpretation of the satellite imagery, to represent different interpretation of the satellite imagery, to represent different interpretation units. It was found during field work that most of the points corresponded in reality with a different land form unit and this we felt was a step towards proving both the validity and the accuracy of the interpretation lines.

The problem of orientation in the field and locating particular points on the imagery was well solved through the use of a series of transparent maps at the scale of the imagery which we superimposed on the imagery. These maps were produced before the fieldwork by the Cartography Dept. of ITC photographically reducing or enlarging an existing 1:200.000 topographical map of the region.

III. RESULTS AND DISCUSSION

3.1 General

The imagery of the M.S.S. system of the ERTS-1 satellite is influenced primarily by the surface conditions of the earth and secondly by factors such as atmospheric absorption, system irregularities etc. The surface conditions include plant coverage both in kind and degree, surface moisture, texture of topsoil, color of top soil, surface stones, rock outcrops, slope in both shape and degree, etc. Most of these conditions, with the exception of plant coverage, relate to the top horizon of a soil profile. Because in most cases the top of the soil reflects conditions occurring deeper in the profile, there are strong reasons to examine the use of the ERTS-1 M.S.S. imagery in conducting soil surveys. Even in the cases where the plant coverage is the dominant factor, the knowledge of the soil-plant relationship could give good hints about the soil situation. The above holds true for both M.S.S. imagery as taken by the ERTS-1 Satellite and conventional aerial photography. The added dimension with the ERTS-1 M.S.S. is the production of four different images for the same area. A number of methods were tried to take advantage of this fact and efforts made to compensate for the poor resolution and lack of stereoscopy. Some of the preliminary results will be given below.

3.2 Various landforms on different bands of ERTS-imagery.

Of the four different images produced by different M.S.S. bands, band 4 was the least useful. It was generally too dark and it seems likely that the atmospheric scattering plays a more important part at these frequencies. Almost all the landform units were better visible in the other bands. The one exception was some areas with a very sandy surface, probably of aeolian origin. These areas could be quite well distinguished on band 4.

The images of band 5, 6 and 7 were more useful. Band 5 seemed to be more influenced by the color of the surface stones and bands 6 and 7 by the moisture conditions and plant coverage. Human constructions like roads, towns, etc. were better visible in band 5, and water bodies in bands 6 and 7.

The resolution on all three bands, 5, 6, 7 was similar and within the limit of 100 m as predicted before launch of the satellite. In one case a road and a railroad could be easily distinguished,

although the total width of each of them as measured in the field, was not more than 15 m including drainage ways at the side and a grassy strip along them. This, however, was an exceptional case of a road running perpendicular to the scanning direction through an area of dark soils. In general roads are not so well visible because most of them are narrower than the limit of resolution.

A comparison between the appearances of different land types inside the valley of Guadiana River which correspond with certain soil associations, shown on bands 5 and 6 are shown below. The facility of drawing an interpretation line is indicated as mappability. The remarks on band 6 are valid also for band 7.

A_1 ALLUVIAL VALLEY OF GUADIANA

A_{11} Recent deposits.

Appearance: Band 5 moderate grey toned matrix with appearances of former channels in darker lines.

Band 6: moderate grey tone. Former channels not visible, unless they hold some water. In this case they are better visible in band 5.

Mappability: moderate of band 5, worse in band 6.

A_{12} Lower terrace plain.

Appearance: Band 5 salt and pepper texture due to small cultivated fields.

Band 6 same as band 5.

Mappability:moderate to good. Some difficulty at the border with unit A14. Better in band 5 than in band 6.

A_{13} Lower mudflow plain. (areas with heavier soils than those in unit A12)

Appearance: Band 5 same as unit A12 but darker grey tones.

Band 6 same as band 5.

Mappability: Band 5 moderate.
Band 6 good. Some difficulties at the border with unit A15.

A_{14} Higher terrace/plain.

Appearance: Band 5 moderate grey tone with some salt and pepper texture.

Band 6 similar to band 5.

Mappability: moderate to good. Slightly better of band 5 than band 6.

A_{15} Higher mudflow plain (areas with heavier soil than those in unit A_{14})
Appearance: Band 5 and 6. Dark patches inside unit A14.
Mappability: Band 5 moderate.
Band 6 good.

Of other landtypes, the areas covered by heavy soils (miocene clays) are extremely well presented on bands 6 and 7. One of the reasons for this could be the fact that on these areas grapes and olives are grown so that at the time of imagery (9th of March) a very thin plant coverage was present in contrast with the adjacent areas. Hilly and mountainous areas are well distinguished from the rest but it is difficult to differentiate them according to rock types (e.g. granite-quartzite-limestone). Mappability generally better in band 6, than band 5. Differentiation of colluvial valleys inside the units is feasible due to the darker grey tones. Areas covered by coarse (sandy) materials have generally good mappability in band 5 and moderate in bands 6 and 7. Differentiation of lower categorical units possible.

The above results indicate that a color composite picture should include at least band 5 and one of the band 6 or 7. The following interpretation maps at scales of 1/1.000.000 and 1/250.000 were traced on color composites of bands 4, 5 and 6, which were completed to simulate a false color image. So band 4 has a blue influence on the picture, band 5 green and band 6 red.

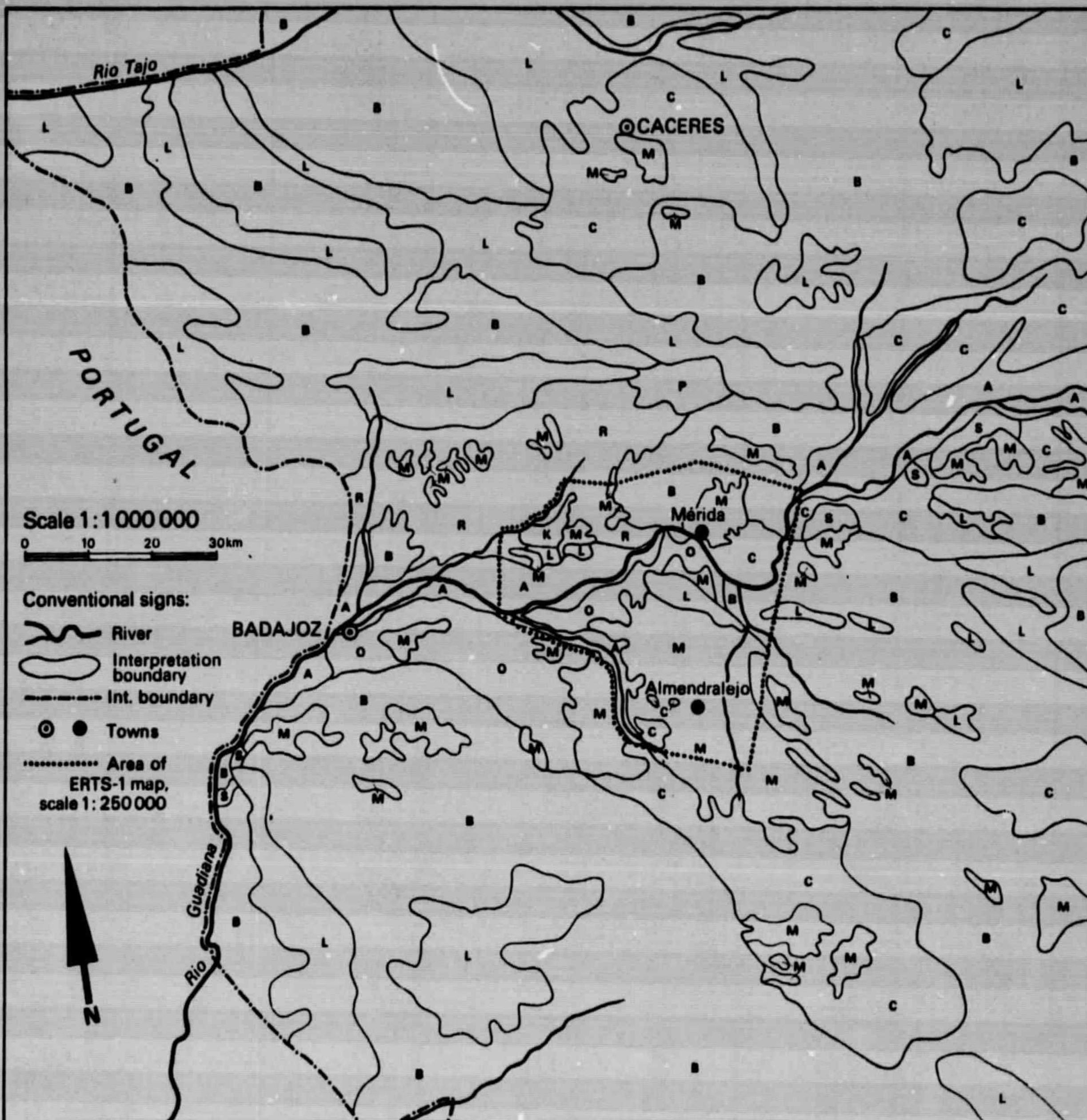
3.3 Comparison of ERTS-1 imagery interpretation with existing maps.

A series of two interpretation maps based on one season (March '73) ERTS-1 imagery for soil survey purposes are presented on two different scales. Both maps were drawn on color composite paper prints prepared by the Photographic Dept. of ITC. The composites were made using bands 4, 5 and 6 with corresponding blue, green and red filters. In this way a simulated false color appearance was achieved. The composite was made of bulk material received from NASA before correction of the original negatives. As a consequence the influence of band 4 was limited due to low contrast.

3.3.1 ERTS-1 Interpretation map and Soil Map of Spain, scale 1:1.000.000.

The ERTS-1 map, scale 1:1.000.000 (Fig.2) was interpreted using available

ERTS-1 IMAGERY INTERPRETATION MAP FOR SOIL SURVEY



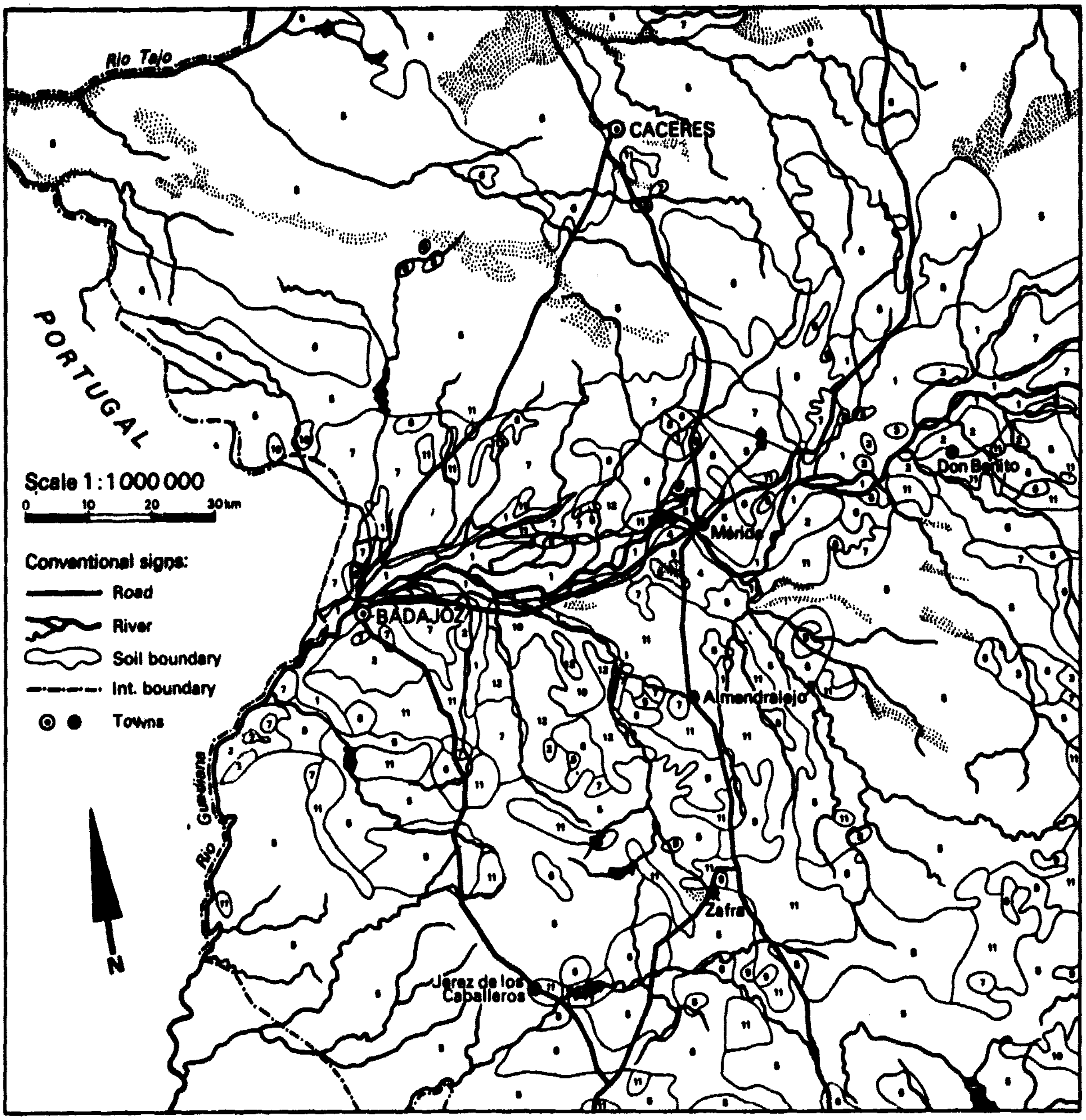
LEGEND

A	Alluvium	K	Undulating to rolling landscape on arkose
S	Aeolian deposits	P	Piedmont on unconsolidated metamorphic material
R	Undulating landscape on rañas, miocene clays and metamophic & sed. rocks	L	Steep hills and mountains of metamorphic & igneous rocks
M	Gently undulating to undulating landscape on miocene clay	B	Rolling to hilly landscape on metamorphic & igneous rocks
O	Undulating to rolling landscape on arkose, conglomerates, clays and rañas	C	Undulating landscape on metamorphic & igneous rocks

Fig.2

Interpretation map of ERTS-1 imagery using a simulated false color composite of bands 4,5 and 6; with limited field check. ITC, Enschede, 1974.

S.W. PART OF THE SOIL MAP OF SPAIN



LEGEND

- 1 Alluvial & colluvial soils
- 2 Sands & dunes
- 3 Xerorankers on silicious material; A/C profile
- 4 Humid brown earths on silicious material; A/(B)/C profile
- 5 Mediterranean brown earths on metamorphic rocks; A/(B)/C profile
- 6 Mediterranean brown earths on igneous rocks; A/(B)/C profile
- 7 Allochtonous brown gravelly soils; A/(B)/C profile
- 8 Calcic brown earths with eluviation of carbonates; A/(B)/C profile
- 9 Calcic brown soils; A/(B)/C profile
- 10 Red mediterranean soils on silicious material; A/B/C profile
- 11 Red mediterranean soils on calcareous material; A/B/C profile
- 12 Lithomorphic vertisols
- Association with lithosols

Fig.3

Part of the Soil Map of Spain adapted from: 'Mapa de Suelos de España', scale 1:1000000, Instituto Nacional de Edafología y Agrobiología del C.S.I.C., Madrid, 1966.

Table 1: Physiography, lithology, natural vegetation/landuse and soils of ERTS-1 Interpretation, S.W. Spain

Scale 1:1000.000

Symbol	Physiography	Lithology	Nat. veg./landuse	Soils
A	Alluvium	Alluvium	Intensively cultivated mainly irrigated, small parcelling	Sandy, loamy & clayey soils; AC, A(B)C profiles
S	Aeolian deposits	Sandy	Grapes	Sandy soils, overlying clay; AC profile
R	Undulating	Rañas, miocene clay, metamorphic & sedimentary rocks	Cultivated & plantation; encinas, cork trees, figs	Reddish brown, medium and heavy textured soils; AC; A(B)C; ABC profiles
M	Gently undulating to undulating	Miocene clay	Grapes & olives (dominant) and cereals	Reddish clay soils, often with (petro) calcic horizon; AC profile
O	Undulating to rolling	Arkose, conglomerates clays, rañas	Olives and cereals	Light brown to reddish brown med. textured soils; A(B)C & ABC profiles.
K	Undulating to rolling	Arkose	Olives (dominant), grapes and cereals	Light brown sandy loams; A(B)C & ABC profiles
P	Piedmont	Unconsolidated metamorphic material	Partly cultivated; planted forest: cork trees & encinas	Reddish brown gravelly loams with argillic horizon; ABC profiles
C	Undulating	Metamorphic & igneous rocks	Cultivated, mainly cereals	Mod deep, brown, med. textured soils A(B)C & ABC profiles
B	Rolling to hilly	Metamorphic & igneous rocks	Forest (encinas) & pasture	Shallow brown med. textured soils; A(B)C, ABC profiles.
L	Steep hills & mountains	Metamorphic, igneous rocks	Poor natural forest (encinas) & bushes	Lithosols; AC profile

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sources of literature and a limited amount of field check (3 weeks). Table 1 contains the summarized results of the fieldwork regarding physiography, lithology, natural vegetation/landuse and soils; 10 mapping units have been distinguished. The soils have been described in simple terms of color, texture, soil depth and profile development.

Comparison to the S.W. part of the Soil Map of Spain[1] of the same area (Fig. 3) is difficult because the legends are built up in a different way. Physiography as expressed in colortone (hue, value, chroma) and color pattern (texture) on the color composite in conjunction with field work have been used for the interpretation of the ERTS-1 image. Soil characteristics in conjunction with lithology have been used as differentiating criteria of the soil Map of Spain. The results and discussion of this comparison are to be found in Table 2.

Conclusions reveal that the interpretation of ERTS-1 imagery was successful with respect to both physiography & lithology for approximately 1/3 of the total survey area of 25.000 km^2, covering Alluvial valleys (A), Aeolian deposits (S), Complex of rañas, miocene clay, metamorphic and sedimentary rocks (R), and Miocene clay (M).
The interpretation was moderately well done in approximately 2/3 of the survey area (physiography: good; lithology: poor) covering the following areas mostly developed on metamorphic and igneous rocks: Undulating (C), undulating to rolling (O), rolling to hilly (B) and steep hills and mountains (L).
THe ERTS-1 interpretation failed completely in approximately 5% of the area (Soil Map of Spain: units 3, 8, 9) covering parts of the undulating, rolling and hilly areas developed on metamorphic and igneous rocks (B & C.).

3.3.2 ERTS-1 interpretation, Soil Map Badajoz and Soil Map with API.

A second map was interpreted independently on an enlargement of a part of the former ERTS color composite print on a scale of 1:250.000. The field check in this area was considerably more: 7 weeks. A physiographic soil map of the Mérida area with 24 mapping units based on the above interpretation is presented in figure 4. The summarized results of the interpretation and field work showing physiography, vegetation/landuse and dominant soils (soil class acc. 7th. Approx., USDA, 1967) may be found in the legend.

1) Instituto Nacional de Edafologiá y Agrobiologiá del C.S.I.C., Madrid, 1966.

Table 2: Comparison of ERTS-1 interpretation with Soil Map of Spain, 1:1.000.000

Mapping Symbols SMS	ERTS-1	Comparison of analysis	Soil Map of Spain	ERTS-1 Interpr.
1	A	Analysis fits well	+	+
2	S	Analysis fits well, probably better on ERTS-1 map	0	+
3	B	Not recognized on ERTS map; area of limited extent, < 1%	+	–
4	M + 0	Analysis not coinciding's complex area	+	–
5+6	C	Analysis of ERTS-1 imagery is based upon physiography. Soil Map of Spain based upon profile characteristics and lithology. Geological structures, drainage and vegetation/landuse show on ERTS-imagery. Lithology difficult. Hence different mapping criteria. Moderate rating for both approaches. Area > 50%	0	0
5+6	B		0	0
5+6	L		0	0
7	R	Analysis fits well; little difference in judgement on profile development	+	+
8	B	Analysis not coinciding, probably wrongly interpreted on ERTS-1 imagery; area of limited extent, approx. 1%	+?	–
9	C	Not recognized; this unit is included in 5+6 during ERTS-interpretation	+?	–
10	M	Analysis both of 10 & 11 fits well at higher level of interpretation; extent as well as soil classification of units of Soil Map of Spain may require revision; the miocene clay area is one of the best recognizable landforms on ERTS-1 imagery	0	–
11	M		0	–
12	0	Analysis not coinciding; highly complex area which is not reflected in existing 1:1.000.000 on Soil Map of Spain.	+?	0

Ratings: + = good; 0 = moderate, – = poor

PHYSIOGRAPHIC SOIL MAP OF THE MÉRIDA REGION
based on ERTS-1 imagery interpretation

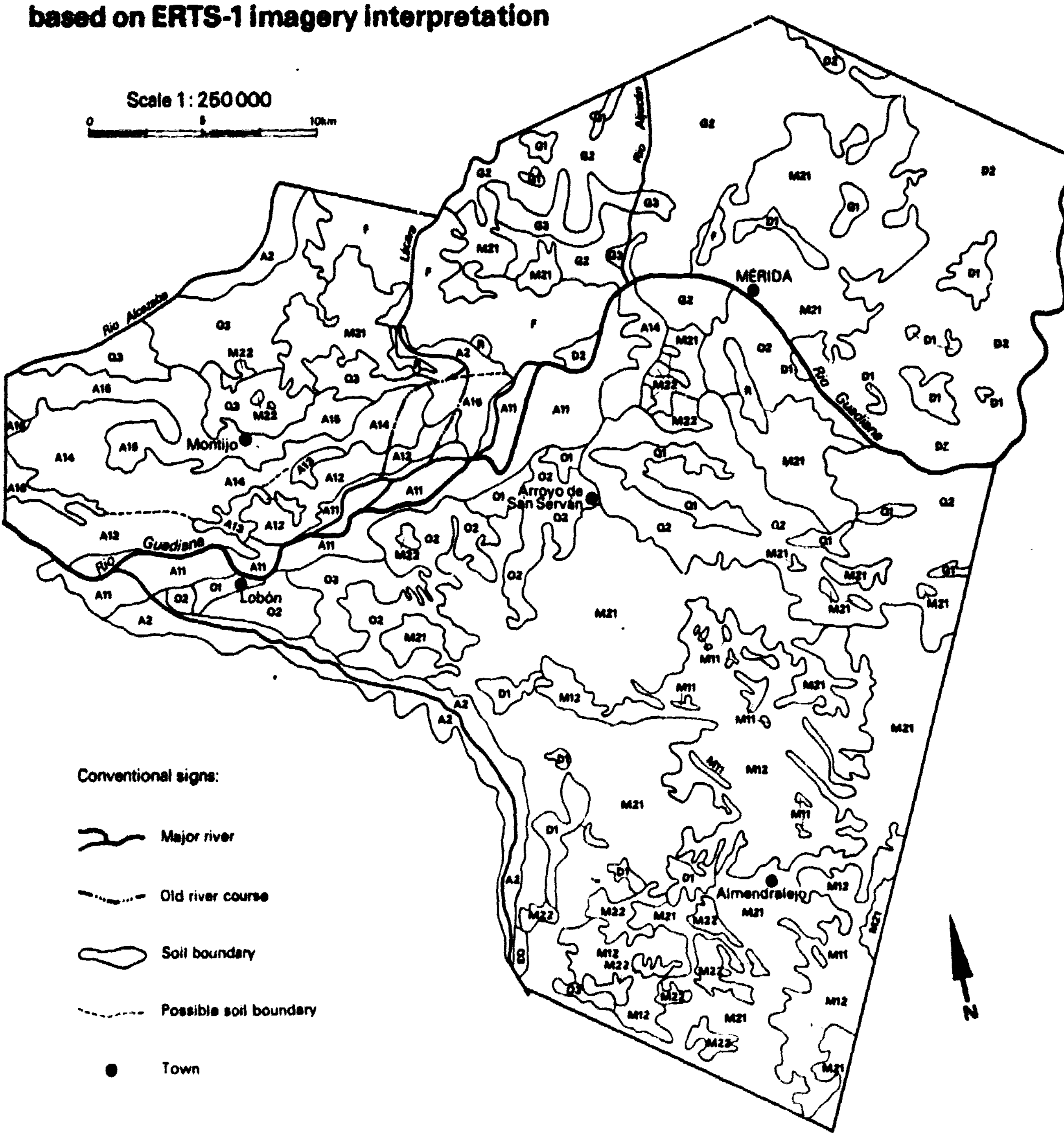

Fig.4 Physiographic Soil Map of the Mérida Region based on ERTS 1 imagery interpretation using an enlarged simulated false color composite of bands 4,5 and 6; with field check. ITC, Enschede, 1974.

LEGEND

PHYSIOGRAPHIC SOIL MAP OF THE MERIDA REGION

SYMBOL	PHYSIOGRAPHY	VEGETATION / LANDUSE	DOMINANT SOILS
A	ALLUVIAL VALLEYS		
A_1	Guadiana valley		
$\boxed{A_{11}}$	Recent deposits	Cultivated; mainly irrigated; small parcels; crops: cereals, maize; horticulture, orchards	Quartzipsamments
$\boxed{A_{12}}$	Lower terrace	- do -	Xerochrepts
$\boxed{A_{13}}$	Lower mudflow plain	- do -	Haploxeralfs (?)
$\boxed{A_{14}}$	Higher terrace	- do -	Xerochrepts
$\boxed{A_{15}}$	Higher mudflow plain	- do -	Haploxeralfs & Chromoxererts
$\boxed{A_{16}}$	Complex with alluvium of tributaries	- do -	Haploxeralfs
$\boxed{A_2}$	Valleys of tributaries	Cereals, olives & grapes	Xerochrepts
$\boxed{R}$	RAÑAS[1]	Grapes & cereals	Haploxeralfs
M	NEARLY LEVEL TO UNDULATING LANDSCAPE ON MIOCENE CLAY		
M_1	Nearly level to gently undulating		
$\boxed{M_{11}}$	Convex summits	Olives & grapes	Xerochrepts
$\boxed{M_{12}}$	Nearly level complex	- do -	Chromoxererts
M_2	Undulating		
$\boxed{M_{21}}$	Complex	Olives & grapes	Xerochrepts & Chromoxererts
$\boxed{M_{22}}$	Depressions	- do -	Chromoxererts
O	UNDULATING TO ROLLING LANDSCAPE ON OLIGOCENE		
$\boxed{O_1}$	Erosion terrace	Cereals, olives & grapes	Haploxeralfs
$\boxed{O_2}$	Complex of arkose, clays & rañas	- do -	Xerochrepts & Haploxeralfs
$\boxed{O_3}$	Arkose	Olives & encinas	- do -
Q	SILURIAN QUARTZITE HILLS		
$\boxed{Q_1}$	Rocky summits	Bare	Xerothents
$\boxed{Q_2}$	Slopes	Poor forest, partly cultivated	Xerochrepts
$\boxed{Q_3}$	Complex	Encinas, partly cultivated	Xerothents & Xerochrepts
$\boxed{F}$	ROLLING LANDSCAPE ON CAMBRIAN LIMESTONE		
	With remnants of miocene clay	Cereals, sunflowers, grapes & olives	Xerochrepts & Haploxeralfs
G	UNDULATING TO ROLLING LANDSCAPE ON CAMBRIAN GRANITE		
$\boxed{G_1}$	Undulating with remnants of miocene clay	Encinas, pasture, partly cultivated	Haploxeralfs
$\boxed{G_2}$	Rolling	Encinas, pasture	Xerorthents
$\boxed{G_3}$	Colluvial valleys	Encinas, pasture, partly cultivated	Xerochrepts & Haploxeralfs
D	UNDULATING TO ROLLING LANDSCAPE ON CAMBRIAN DIORITE AND SCHISTS		
$\boxed{D_1}$	Undulating with remnants of miocene clay	Cereals	Haploxeralfs
$\boxed{D_2}$	Rolling	Pasture, partly cultivated	Haploxeralfs

[1] Pliocene/pleistocene braided river deposits

A comparison was made with the existing Soil Map of the Province of Badajoz (C.S.I.C., Madrid, 1968) scale 1:250.000 and also with a physiographic soil map, scale 1:100.000, based on aerial photo-interpretation and field check (ITC, student field work 1973). The results and discussion are presented in Table 3. The comparison of the ERTS-1 map with the ITC soil map based on API is easier because both legends have a physiographic basis, while the Soil Map of Badajoz is mainly based on profile characteristics, though more detailed than those of the Soil Map of Spain.

Conclusions regarding Table 3 reveal that the ERTS-1 imagery interpretation was successful for 17 mapping units covering 3/4 of the whole survey area of the Mérida Region (1200 km^2). Sub-divisions with a good measure of accuracy were possible in the alluvial valleys (A), the miocene clay (M). Further analysis was coincided well in the erosion terrace (O_1), the complex of arkose, clay and rañas (O_2), the arkose (O_3) and finally the undulating to rolling area on granite (G).

The ERTS-1 interpretation was moderately successful in 7 mapping units, covering approximately 1/4 of the Mérida Region as the lithology could not always be recognized and delineated. This refers to the following areas: Rañas (R), Quartzite hills (Q), Rolling on limestone (F) and undulating to rolling on diorite (D). More observations in these areas would be needed.

Table 3: Comparison of ERTS-1 interpretation map 1:250.000 with Soil Map Badájoz Scale 1:250.000 and ITC Student Soil Map Scale 1:100.000 based on aerial photo-interpretation.

Mapping Symbol ERTS-1	Phys. Soil Map ERTS-1 1:250.000	Symbol API	Phys. Soil Map API 1:100.000	Symbol SMB	Soil Map Province Badajoz 1:250.000 (SMB)	ERTS-1	API	SMB
A	Alluvial valleys	A	Well coinciding	1	Coinciding, except border N.W. of Montijo (inclusion of soils on shales & arkose)	+[1]	+	+
O	Undulating to rolling on oligocene							
O_1	Erosion terrace	F	Well coinciding except area South of Mérida	2a, 8, 13	Differ mainly because of survey approach a.p.i. & ERTS interpretation (phys.) versus soil chars	+	+	0
O_2	Complex of arkose, clays and rañas	O, C	Generally well coinciding	8	Agrees in extent, but not in contents; very complex unit mapped as a single unit on S.M.B.	+	+	0
O_3	Arkose	O	Generally well coinciding	8, 13	Delineation coincides, see further above.	+	+	0
R	Rañas	R	Moderately well coinciding Some units not visible on ERTS-1 imagery	13	Moderately well coinciding; too generalized unit N of Montijo and S. of Rio Alcazaba wrongly interpreted unit (arkose)	0	+	0
M	Miocene clay	M	Generally well coinciding sub-divisions differ. Group II has interchanged M_1 and M_2	3, 4c, 10, 13b, 15c,	Delineation of M as a whole mod. well coinciding, extent not so accurate; phys. not well expressed; description of soils differ; distribution of sub-units within M quite different (phys.!)	+	+/0	0/-
Q	Quartzitic hills	S	Generally well coinciding more generalized in ERTS-1 map; some limestone interpreted as quartzite N.E. of Montijo on ERTS-1 map.	4a, 5b, 9a,	Differs from lithology in the field; Sierra de San Serván is mainly quartzite; area S. of Guadiana river (near Don Alvaro) is schist. Hilly area N. of Torremayor is to a limited extent limestone, but mainly Quartzite.	+/0	+	-
F	Rolling on limestone	L	Coinciding mod. well; more generalized in ERTS-1 map	4a, 10	mod. well coinciding with regard to geographical extent	0	+	0
G	Undulating to rolling on granite	G	Well coinciding	5c	Well coinciding, more generalized; rocks are all intrusive acidic rocks	+	+	+
D	Undulating to rolling on diorite and schists	D	Mod. well coinciding, on ERTS-1 map schists are included; comparison difficult	5c, 7b	Moderately well coinciding units are more generalized in soil map of Badajoz	0	+	0

[1]) qualitative rating of coincidence with regard to field check: + good, 0: moderate -: poor

IV. GENERAL CONCLUSIONS

ERTS-1 imagery promises to be very valuable for generalized to exploratory soil surveys at small scales up to 1 : 500,000, valuable for reconnaissance surveys at scales up to 1 : 100,000 and useful for surveys at scales up to 1 : 50,000 in conjunction with conventional aerial photo-interpretation. Moreover it seems to a valuable tool for updating existing soil maps at scales as mentioned above.

For the Mérida Region, Spain, independent interpretations on color composite enlargements of ERTS-1 imagery (scale 1:250,000) show a better coincidence with existing soil maps than interpretations on the standard 9 inch format, scale 1:1,000,000. This may be explained by the fact that much information is stored on the ERTS image which is better retrieved on enlargements. However, the amount of observations also plays an important role. It should be noted that the 1:1,000,000 scale ERTS interpretation map for a generalized soil survey was done with a minimum of field check. For the Physiographic Soil Map scale 1:250,000 based on ERTS imagery, considerable more time was spent for verification.

Experiments with the I^2S Color Additive Viewer have revealed a better discrimination of some landforms in other band, filter and illumination combinations than the simulated false color image (4-blue, 5-green, 6-red). A methodology should be developed for further study. The best combination probably depends highly on the physiography of the area and the season in which the imagery was taken, apart from the quality (resolution, contrast) of the original products.

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